Artificial intelligence-enhanced electrocardiography in cardiovascular disease management

Year: 2021 | Citations: 638 | Authors: K. Siontis, P. Noseworthy, Z. Attia, P. Friedman

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Abstract

The application of artificial intelligence (AI) to the electrocardiogram (ECG), a ubiquitous and standardized test, is an example of the ongoing transformative effect of AI on cardiovascular medicine. Although the ECG has long offered valuable insights into cardiac and non-cardiac health and disease, its interpretation requires considerable human expertise. Advanced AI methods, such as deep-learning convolutional neural networks, have enabled rapid, human-like interpretation of the ECG, while signals and patterns largely unrecognizable to human interpreters can be detected by multilayer AI networks with precision, making the ECG a powerful, non-invasive biomarker. Large sets of digital ECGs linked to rich clinical data have been used to develop AI models for the detection of left ventricular dysfunction, silent (previously undocumented and asymptomatic) atrial fibrillation and hypertrophic cardiomyopathy, as well as the determination of a person's age, sex and race, among other phenotypes. The clinical and population-level implications of AI-based ECG phenotyping continue to emerge, particularly with the rapid rise in the availability of mobile and wearable ECG technologies. In this Review, we summarize the current and future state of the AI-enhanced ECG in the detection of cardiovascular disease in at-risk populations, discuss its implications for clinical decision-making in patients with cardiovascular disease and critically appraise potential limitations and unknowns. In this Review, Friedman and colleagues summarize the use of artificial intelligence-enhanced electrocardiography in the detection of cardiovascular disease in at-risk populations, discuss its implications for clinical decision-making in patients with cardiovascular disease and critically appraise potential limitations and unknowns. The feasibility and potential value of the application of advanced artificial intelligence methods, particularly deep-learning convolutional neural networks (CNNs), to the electrocardiogram (ECG) have been demonstrated. CNNs developed with the use of large numbers of digital ECGs linked to rich clinical datasets might be able to perform accurate and nuanced, human-like interpretation of ECGs. CNNs have also been developed to detect asymptomatic left ventricular dysfunction, silent atrial fibrillation, hypertrophic cardiomyopathy and an individual's age, sex and race on the basis of the ECG alone. CNNs to detect other cardiac conditions, such as aortic valve stenosis and amyloid heart disease, are in active development. These approaches might be applicable to the standard 12-lead ECG or to data obtained from single-lead or multilead mobile or wearable ECG technologies. Evidence on patient outcomes, as well as the challenges and potential limitations from the real-world implementation of the artificial intelligence-enhanced ECG, continues to emerge. The feasibility and potential value of the application of advanced artificial intelligence methods, particularly deep-learning convolutional neural networks (CNNs), to the electrocardiogram (ECG) have been demonstrated. CNNs developed with the use of large numbers of digital ECGs linked to rich clinical datasets might be able to perform accurate and nuanced, human-like interpretation of ECGs. CNNs have also been developed to detect asymptomatic left ventricular dysfunction, silent atrial fibrillation, hypertrophic cardiomyopathy and an individual's age, sex and race on the basis of the ECG alone. CNNs to detect other cardiac conditions, such as aortic valve stenosis and amyloid heart disease, are in active development. These approaches might be applicable to the standard 12-lead ECG or to data obtained from single-lead or multilead mobile or wearable ECG technologies. Evidence on patient outcomes, as well as the challenges and potential limitations from the real-world implementation of the artificial intelligence-enhanced ECG, continues to emerge.